

# The future of radiometry fits into your hand

The emergence of new environmental observation platforms such as aerial drones and small satellites, and the requirements for remotely located observations, e.g. from buoys, have pushed conventional radiometer design to its limits. These applications require a new approach to radiometer design, with an emphasis on small, integrated, low power radiometer units that provide robust and reliable performance for an affordable price.

Boulder Environmental Sciences and Technology has been working on the development of compact radiometer receivers, with focus on reducing their size, weight and power consumption. In addition, our receivers have also improved sensitivity, reliability, and calibration accuracy. They are designed as a “plug and play” solution for platforms such as unmanned aerial vehicles or nanosatellites (CubeSats) for atmospheric observations. The user simply needs to connect power and measure the analog output signals.

The radiometers and their receivers presented here are designed specifically for atmospheric observations. In addition, they offer the following features:

- Smallest radiometers on the market
- Improved receiver sensitivity, reliability, stability, and calibration accuracy despite their small size
- Direct detection radiometer architecture is used, thus oscillator drift is not an issue
- Two internal calibration points are provided for continuous gain and offset evaluation
- No thermal stabilization is required
- Operational temperature range is  $-40^{\circ}\text{C}$  to  $+50^{\circ}\text{C}$
- Designed for mass production to reduce cost
- User friendly, integrated solution for your observational needs

## 150 GHz dual polarization, two channel radiometer

A layout of a 150 GHz radiometer is shown in Figure 1. All dimensions are in millimeters. The radiometer antenna has  $5^{\circ}$  half power beamwidth. The Ortho-Mode Transducer (OMT) divides the incoming electromagnetic waves into two orthogonal linear polarization outputs. Observations in two polarizations are redundant to provide an advantage in data evaluation and analysis. The radiometer has two receivers, one per polarization, Receiver 1 and 2. Each of the receivers has two parts, a and b. The complete radiometer, as shown in Figure 1, consumes less than 1 W of power and its weight is about 100 grams.

Table 1. 150 GHz radiometer channels

Channel frequency (GHz)	center (MHz)	Bandwidth (MHz)	Radiometer sensitivity* (K)
150		3000	0.17
165		3000	0.17

\*Radiometer sensitivity is evaluated for 10 ms integration time.

The 150 GHz radiometer has two channels in the atmospheric window between the 118 GHz oxygen absorption line and the 183 GHz water vapor absorption line. The channels' center frequencies are at 150 and 165 GHz. Similar channels are used by various microwave instruments on operational satellites such as AMSU-B, SSM/T-2, SSMIS, and GMI, ATMS, respectively. The measurements of these channels are used mainly for cloud properties and precipitation retrievals. The radiometer parameters are listed in Table 1.

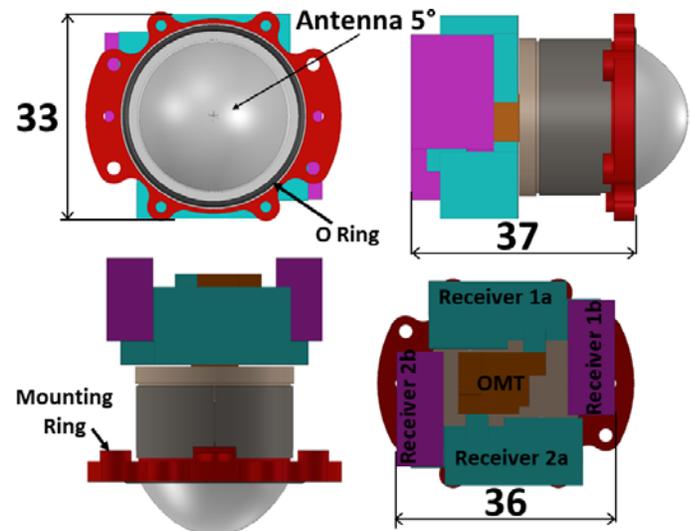


Figure 1. A mechanical layout of the 150 GHz, dual polarization, two channel radiometer. All dimensions are in millimeters.

# 183 GHz dual polarization, five channel radiometer

The 183 GHz radiometer has five channels on the upper wing of the 183.31 GHz water vapor absorption line. The channels span ~182 to ~198 GHz, covering the absorption line center as well as the atmospheric window. This radiometer's measurements can be used primarily for retrieval of vertical profile of humidity of the atmosphere and clouds ice parameters. Dual polarization provides redundancy in retrievals and can provide additional information about cloud particles.

The layout of the receiver is shown in Figure 2. All dimensions are in millimeters. The radiometer antenna has 5° half power beamwidth. The complete radiometer, as shown in Figure 2, consumes less than 1 W of power and its weight is about 150 grams.

Table 1. 183 GHz radiometer channels

Channel center frequency (GHz)	Bandwidth (MHz)	Radiometer sensitivity* (K)
183.31	1900	0.27
185.21	1900	0.27
188.16	4000	0.19
192.16	4000	0.19
196.16	4000	0.19

\*Radiometer sensitivity is evaluated for 10 ms integration time.

The temperature weighting functions, shown in Figure 3, indicate the sensitivity of the individual receiver's channels to various levels of the atmosphere. Simulated observations are from 20km altitude and the nadir view corresponds to 0°. When a radiometer is pointed away from the nadir, the weighting functions' peaks are sharper and peak higher in the atmosphere. There is basically no difference in observations between the land and sea surface. This is because the channels are attenuated in the atmosphere and are not sensitive to surface below.

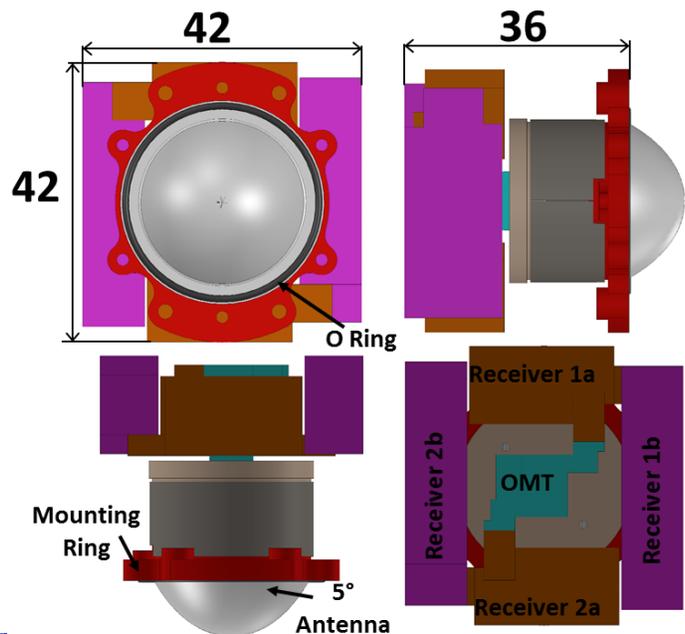


Figure 2. A mechanical layout of the 183 GHz, dual polarization radiometer. All dimensions are in millimeters.

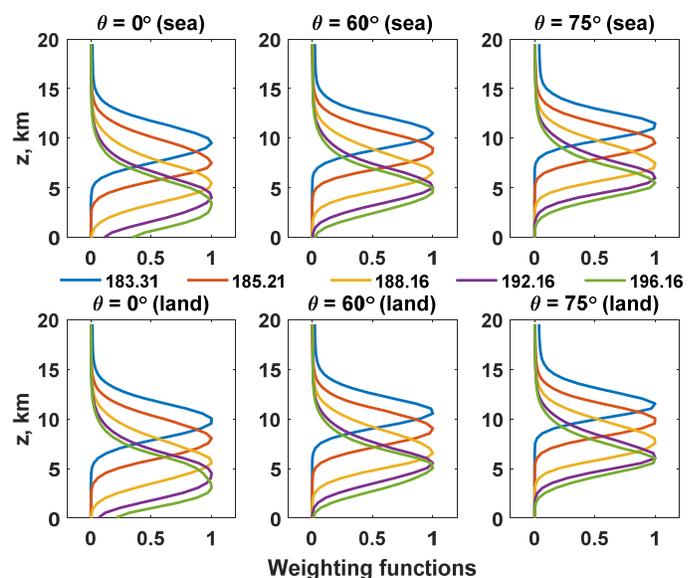


Figure 3. The temperature weighting functions for a nadir looking radiometer located above the atmosphere (~20,000 m altitude) for various incident angles and background surfaces.



We are planning the development of a similar receiver operating between 90 and 119 GHz for atmospheric temperature profiling.





# 150 GHz dual polarization, two channel radiometer

A layout of a similar radiometer for 150 GHz is shown in Figure 3. All dimensions are in millimeters. The radiometer antenna has 5° half power beamwidth. The complete radiometer, as shown in Figure 3, consumes less than 1 W of power and its weight is about 100 grams.

Table 2. 150 GHz radiometer channels

Channel frequency (GHz)	center (MHz)	Bandwidth (MHz)	Radiometer sensitivity* (K)
150		3000	0.17
165		3000	0.17

\*Radiometer sensitivity is evaluated for 10 ms integration time.

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Similar channels are used by various microwave instruments on operational satellites such as AMSU-B, SSM/T-2, SSMIS, and GMI, ATMS, respectively. The measurements of these channels are used mainly for cloud properties and precipitation retrievals. The radiometer parameters are listed in the Table 2.

Observations in two polarizations are redundant to provide an advantage in data evaluation and analysis.

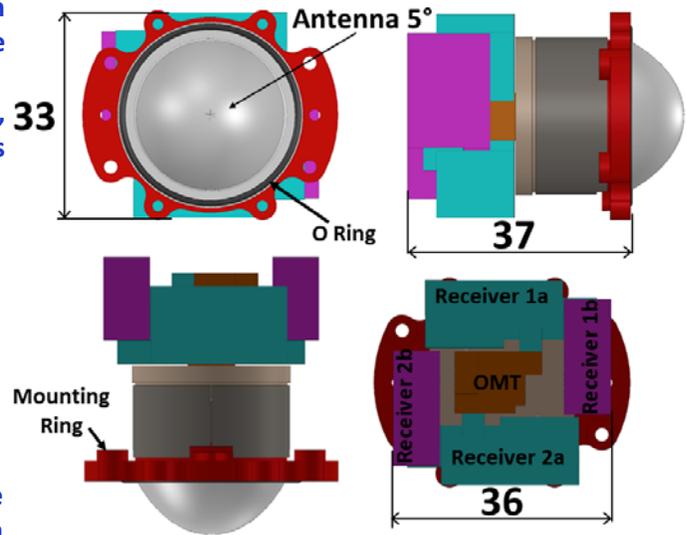


Figure 3. A mechanical layout of the 150 GHz, dual polarization, two channels radiometer. All dimensions are in millimeters.



## Future plans

We are planning a development of a similar receiver operating between 90 and 119 GHz for atmospheric temperature profiling.

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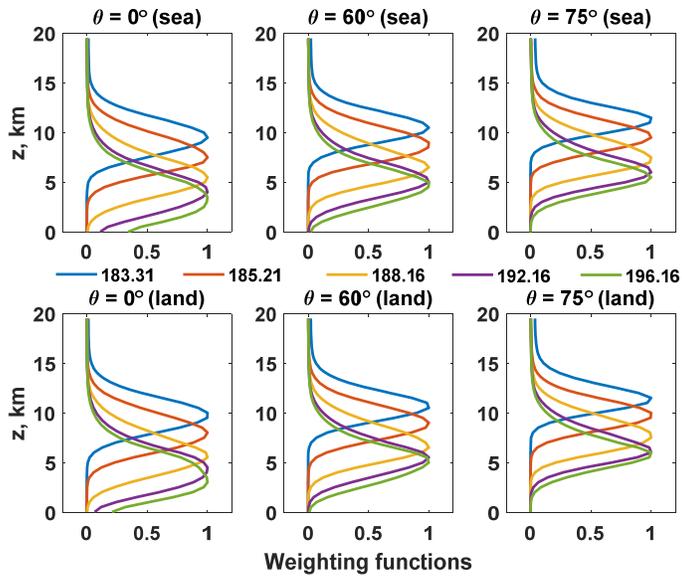
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Normalized weighting function with linear axis of altitude

